

ARI Research Note 91-21

AD-A231 887

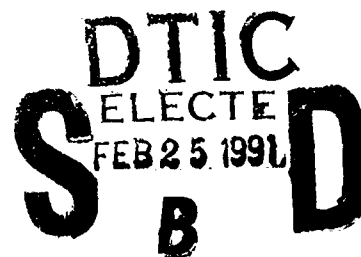
The Selection of an Experimental Test Battery for Aviator Cognitive, Psychomotor Abilities and Personal Traits

Gabriel P. Intano, William R. Howse, and Ronald J. Lofaro
U.S. Army Research Institute

ARI Aviation R&D Activity
Charles A. Gainer, Chief

Training Research Laboratory
Jack H. Hiller, Director

January 1991



United States Army
Research Institute for the Behavioral and Social Sciences

Approved for public release; distribution is unlimited.

91 2 21 028

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

**A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel**

EDGAR M. JOHNSON
Technical Director

JON W. BLADES
COL, IN
Commanding

Technical review by

Dennis C. Wightman

NOTICES

DISTRIBUTION: This report has been cleared for release to the Defense Technical Information Center (DTIC) to comply with regulatory requirements. It has been given no primary distribution other than to DTIC and will be available only through DTIC or the National Technical Information Service (NTIS).

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The views, opinions, and findings in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other authorized documents.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS --	
2a. SECURITY CLASSIFICATION AUTHORITY --			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE --				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) ARI Research Note 91-21			5. MONITORING ORGANIZATION REPORT NUMBER(S) --	
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Research Institute Aviation R&D Activity		6b. OFFICE SYMBOL (If applicable) PERI-IR	7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Fort Rucker, AL 36362-5354			7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Research Institute for the Behavioral and Social Sciences		8b. OFFICE SYMBOL (If applicable) PERI-I	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER --	
8c. ADDRESS (City, State, and ZIP Code) 5001 Eisenhower Avenue Alexandria, VA 22333-5600			10. SOURCE OF FUNDING NUMBERS	
			PROGRAM ELEMENT NO. 63007A	PROJECT NO. 795
11. TITLE (Include Security Classification) The Selection of an Experimental Test Battery for Aviator Cognitive, Psychomotor Abilities and Personal Traits				
12. PERSONAL AUTHOR(S) Intano, Gabriel P.; Howse, William R.; and Lofaro, Ronald J.				
13a. TYPE OF REPORT Interim	13b. TIME COVERED FROM 87/01 TO 87/07	14. DATE OF REPORT (Year, Month, Day) 1991, January	15. PAGE COUNT 29	
16. SUPPLEMENTARY NOTATION --				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD 05	GROUP 08	SUB-GROUP	Army aviation Multi-track training Selection Classification	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) In late 1986, the U.S. Army Aviation Center (USAAVNC) redesigned the Initial Entry Rotary Wing (IERW) course for aviator candidates. The new training is called IERW Multi- Track (IERW-MT) and became operative in May 1988. The research problem for the U.S. Army Research Institute Aviation R&D Activity (ARIARDA) was to develop tests and procedures for selecting aviator candidates for one of four helicopters prior to training day 100. ARIARDA simultaneously pursued two avenues of research. On the one hand, available test instruments were considered and evaluated for their potential to discriminate among aviators. On the other hand, groups of Subject Matter Experts (SMEs) developed criticality-rated aviator can- didate abilities and traits for specific operational helicopters. Extensive literature reviews and liaison with sister services and other agencies were accomplished. Four test instruments were evaluated for use. The underlying abilities, traits, and skills these bat- teries purported to measure matched the abilities, traits, and skills identified as necessary by the SMEs for each of their helicopters. Upon selection of the subtests contained in the (Continued)				
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Charles A. Gainer			22b. TELEPHONE (Include Area Code) (205) 255-4404	22c. OFFICE SYMBOL PERI-IR

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ARI Research Note 91-21

19. ABSTRACT (Continued)

ARIARDA experimental test battery, high-time aviators were given the experimental battery to develop scoring profiles for specific aircraft and to generate the data for the statistical analyses that resulted in the Preliminary Multi-Track Classification Algorithm.



Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

THE SELECTION OF AN EXPERIMENTAL TEST BATTERY FOR AVIATOR COGNITIVE, PSYCHOMOTOR ABILITIES AND PERSONAL TRAITS

CONTENTS

	Page
BACKGROUND	1
SMALL GROUP ANALYSIS	2
Subjects.	2
Procedure	2
Analysis and Results.	3
TEST INSTRUMENTS	5
U.S. Air Force Human Resources Laboratory Basic Abilities Test.	5
U.S. Naval Aeromedical Research Laboratory Multi-Tasking Battery	6
NASA/Helmreich Cockpit Management Attitudes Questionnaire	6
U.S. Army Research Institute Complex Cognitive Assessment Battery.	6
Subjects.	7
Procedure	7
Analysis.	7
Results	7
DISCUSSION	15
REFERENCES	17
BIBLIOGRAPHY	19

LIST OF TABLES

Table 1. Comparison of aviator abilities and traits by helicopter.	4
2. Standardized canonical discriminant function coefficients	10
3. Classification function coefficients	12
4. Direct and jackknife classifications	13
5. Concurrence of battery subtests with small group analyses	14

THE SELECTION OF AN EXPERIMENTAL TEST BATTERY FOR AVIATOR COGNITIVE, PSYCHOMOTOR ABILITIES AND PERSONAL TRAITS

Background

In late 1986, the U.S. Army Aviation Center (USAAVNC) redesigned the Initial Entry Rotary Wing (IERW) course of training for aviator candidates. The new training was called IERW Multi-Track (IERW MT) and became operative in May 1988. The major differences between Multi-Track and the prior IERW are: (1) In IERW the aviation candidate received primary flight training in the reciprocating engine Hughes TH-55. In IERW-MT, primary flight training is obtained in the turbine powered Bell UH-1. (2) In IERW, after completing the primary phase in the TH-55, aviation candidates completed flight training in either the UH-1 or the OH-58. Selection and training for all other aircraft occurred later. In IERW-MT, all candidates receive a common core of flight training in the UH-1 and then earn their wings in the UH-1, OH-58, AH-1 or UH-60 aircraft. The classification in IERW-MT into one of these four helicopter tracks must be made prior to training day (TD) 100, since advanced training in one of the four tracks begins on TD 101.

The research problem for the U.S. Army Research Institute Aviation R&D Activity (ARIARDA) was to develop tests and procedures for classifying aviator candidates into one of the four helicopters prior to TD 100. Discriminating measures were therefore required to assign candidates into a helicopter in which they would have the highest probability of both successfully completing flight training and also having a successful aviation career.

Since there were only eighteen months from the initial tasking to IERW-MT implementation, it was decided to simultaneously pursue two avenues of research. On one avenue, available test instruments were considered and evaluated for their potential to discriminate among aviators already highly qualified in different aircraft. On the other, groups of Subject Matter Experts (SMEs) developed a list of criticality-rated aviator candidate abilities and traits for each of the specific operational helicopters.

At the completion of both research approaches, ARIARDA united the results, linking specific tests with required aviator abilities and traits. The products of these approaches were synthesized into a test battery which could discriminate among Army aviators and provide data from which classification algorithms were derived.

Small Group Analysis

The objective of this research was to identify the skills, abilities, and traits that were essential to successful performance in specific helicopters. The Delphi techniques, originated and refined by the Rand Corporation from 1948 through 1968, are commonly used methodologies for eliciting analyses, expert opinions, and evaluations. Delphi processes have been described as characterized by methods for structuring group processes to facilitate operations on complex problems (Linstone and Turoff, 1975). ARIARDA designed three interrelated modified Delphi workshops and acted as facilitator and trainer for the workshops (Lofaro, 1986). Based on the results of those workshops, Lofaro developed a new paradigm and techniques which were used in the analysis reported here. The traditional Delphi processes were modified in the following ways:

1. Addition of formal instruction for the participants in group processes, group dynamics, and methods of consensus.
2. A guided exercise in group consensus was provided, followed by evaluation and critique of the group techniques by the participants and by the facilitator.
3. Anonymous individual ratings were combined with group discussions and group consensus in systematic steps.
4. For selected group objectives, guidance was provided to ensure the evolution of a data base in a sequential manner related to the steps taken by the group.
5. For other group objectives, group discussion and consensus were the only allowed rating methods.

Subjects. Ten subjects served in each of six workshops. A total of 60 Subject Matter Experts (SMEs), ten representing each of the six helicopter types, were involved. The SMEs were experienced Instructor Pilots or were Commissioned and Warrant Officer Advanced Course attendees. There were 22 Commissioned and 38 Warrant Officers in the sample. In addition, a separate sample of three SMEs for each helicopter type served to validate the results of the workshops.

Procedure. Six separate workshops were conducted--one for each of the aircraft of interest. The procedures for all workshops were identical. Current Aircrew Training Manuals (ATMs) for each of the aircraft were provided to the SMEs. These manuals contain descriptions of maneuvers and tasks required of aircrew members and the standards to which they must be performed for them to be considered competent aviators. Workshop participants were provided with detailed objectives and protocols for the tasks to be accomplished. The individual groups were

provided printed materials specific to their helicopter, including listings of all Aircrew Training Manual (ATM) tasks for their aircraft. The tasks for each group were divided into individual, small group (5 person), and intact group (10 person) iterations for each objective. There were three major objectives for the small group analyses: (a) Identify essential tasks for each helicopter, (b) identify methods for training and performance assessment for the tasks, and (c) identify aviator traits and attributes essential to the successful and superior mission aviator. For each aircraft, two subsets of the ATM tasks were produced. One subset consisted of those tasks perceived as unique to operation of that helicopter; the other consisted of those tasks perceived as essential to operational success. The tasks in these subsets were then rated as to criticality for operational success and safety of operations. Each workshop also produced a consensual set of personal traits identified as necessary to mission success.

Analysis and Results. The lists of ATM tasks and the lists of personal traits were examined for commonality. A small group of tasks and traits were seen as essential for all aircraft, but there were substantial differences between aircraft, both in number and types of tasks included. In the case of the UH-1, however, all of the tasks and traits attributed to that aircraft were common to all of the other aircraft. The essential critical ATM tasks were categorized as to underlying abilities using Fleishman's taxonomic approach (Fleishman and Quaintance, 1984). This preliminary categorization was validated using three SMEs for each aircraft. This was accomplished by the SMEs in groups of three and individually, over a period of one week for each helicopter type. The final categorized list of critical abilities and traits is presented in Table 1.

Table 1

Comparison Of Aviator Abilities And Traits By Helicopter

Aircraft	AH-64	AH-1	OH-58	UH-1	UH-60	CH-47
Cognitive						
Time-Sharing/Divided Attention	Yes	Yes	Yes	Yes	Yes	Yes
Memory						
Long-Term	Yes	Yes		Yes	Yes	Yes
Short-Term	Yes	Yes		Yes	Yes	Yes
Decision-Making	Yes	Yes	Yes	Yes	Yes	Yes
Deductive Reasoning	Yes	Yes	Yes	Yes	Yes	Yes
Visualization	Yes	Yes	Yes	Yes	Yes	Yes
Rule Following/Information Ordering		Yes			Yes	Yes
Pattern Recognition and Detection		Yes	Yes		Yes	Yes
Oral Expression	Yes	Yes			Yes	Yes
Written Comprehension	Yes	Yes	Yes	Yes	Yes	Yes
Personal Traits						
Composure/Stress Handling	Yes					Yes
Decisiveness	Yes					Yes
Adaptability/Flexibility	Yes					Yes
Judgement/Decisions	Yes					Yes
Dedication/Determination	Yes					Yes
Aggressiveness	Yes		Yes		Yes	Yes
Team Player	Yes	Yes				Yes
Communication Skills		Yes		Yes	Yes	
Psychomotor						
Flight Control Precision						
Spatial Orientation	Yes	Yes	Yes	Yes	Yes	Yes
Reaction Time	Yes	Yes	Yes	Yes	Yes	Yes
Speed of Closure		Yes	Yes	Yes		Yes
Rate of Closure			Yes		Yes	Yes
Problem Sensitivity		Yes		Yes	Yes	
Perceptual Speed		Yes		Yes	Yes	

Test Instruments

A literature search and liaison with sister services and other agencies were accomplished. In this effort, the U.S. Air Force, U.S. Navy, Federal Aviation Administration, National Aeronautics and Space Administration and the Army Research Institute became the researchers' main sources of candidate instruments. There were numerous examples of studies of the personal attributes relating to operation of various Army helicopters (ARRO, 1982; Miller, Eschenbrenner, Marco and Dohme, 1981) which, combined with recent work involving the role of attitudinal and motivational traits (Foushee and Helmreich, 1986; Helmreich, 1983; Helmreich, Foushee, Bensen and Russini, 1985), provided a basis for selection of existing test instruments for exploratory development. A bibliography of related works is included in this report. Four existing test instruments were included as candidates because of their availability and their coverage of the domains of interest. In addition, a background questionnaire eliciting biographical information, with an emphasis on flight experience, and a daily activity log, were used to ensure that subjects were not excessively fatigued nor taking prescribed medications at the time of testing.

U.S. Air Force Human Resources Laboratory Basic Abilities Test. The researchers visited the USAF Human Resources Laboratory (HRL) Brooks AFB, TX, to observe the USAF Portable Basic Abilities Test, called the Porta-BAT. The Porta-BAT was developed by the USAF and originally consisted of an interactive set of some 27 sub-tests as well as an activities interest inventory and an aircrew personality profile. Conversations with the USAF personnel involved in BAT development centered around these nine sub-tests: (a) Two Hand Coordination, (b) Complex Coordination (Stick/Throttle), (c) Decision Making Speed, (d) Word Knowledge, (e) Time Sharing, (f) Manikin, (g) Serial Mental Arithmetic, (h) Mental Rotation, 3-D, and (i) Embedded Word Test. USAF personnel had preliminary data which indicated some positive results for these BAT sub-tests. Additionally, the underlying abilities measured by these sub-tests of the BAT were seen as promising discriminators in selection and/or classification. The literature search indicated that there were some abilities which had previously been identified by Army SMEs. The researchers used these abilities as another method of selecting the BAT sub-tests. Therefore, the researchers decided to use these BAT sub-tests as part of their experimental test-battery. The USAF arranged to have one PORTA-BAT unit transported to Fort Rucker for use in the study. Descriptions of the BAT sub-tests used, as well as the underlying psychomotor, psychological and cognitive abilities tapped, are available in Siem & Carretta, 1986; Bordelon & Kantor, 1986 and Kantor & Bordelon, 1985.

U.S. Naval Aeromedical Research Laboratory Multi-Tasking Battery. The same procedure was followed with the US Navy Aerospace Medical Research Laboratory (NAMRL) at NAS Pensacola. The researchers visited NAMRL and were shown aviation selection tests that were, and are, under development there. After discussions and a reading of the available NAMRL literature, it was decided to use their most current multi-tasking psychomotor tests. The NAMRL battery consists of seven computer assisted subtests, gradually increasing in difficulty. The seven tests, increasing in difficulty are: (a) Psychomotor (PMT), Stick Only; (b) Dichotic Listening Task (DLT); (c) Dual (PMT and DLT); (d) Psychomotor (Stick and Rudder); (e) Triple (Stick, Rudder and DLT); (f) Triple (Stick, Rudder and DLT); and (g) Psychomotor (Stick, Rudder and Throttle). The Navy also provided ARIARDA with the software and the hardware to run their test battery. These tests and the necessary apparatus such as joysticks and control pedals are described in Griffin & McBride, 1986.

NASA/Helmreich Cockpit Management Attitudes Questionnaire. The next test battery selected for usage was the Cockpit Management Attitudes Questionnaire (CMAQ), developed by NASA Ames and Dr. Robert Helmreich of the University of Texas at Austin during 1983-1986. Dr. Helmreich used a cluster analysis technique to derive personal attributes and typologies from the CMAQ. The CMAQ Battery consists of the Work and Family Orientation Questionnaire, as modified by Helmreich and Spence (1978); the Revised Jenkins Attitude Survey (currently being used in USN aviator candidate selection) as modified by Pred, Helmreich and Spence (1982); The Extended Personal Attributes Questionnaire (EPAQ), as developed in Spence, Helmreich and Stapp (1974) and Spence and Helmreich (1983), and the Cockpit Management Attitudes Questionnaire developed by Helmreich (1987).

U.S. Army Research Institute Complex Cognitive Assessment Battery. The fourth, and final, test battery selected was the computerized Complex Cognitive Assessment Battery (CCAB) as developed under contract to ARI by EATON Corporation's Analytical Assessment Center. The CCAB was originally developed during 1985-1986 to ascertain the potential effect of chemical defense drugs on the performance of US Army tactical tasks, requiring high-level complex cognitive skills. ARIARDA's analyses of the sub-tests and the theoretical principles which guided their development indicated that the cognitive/psychological abilities identified were those which can also be seen as necessary for aircrew members. The CCAB is composed of the following computerized tests: (a) Tower Puzzle, (b) Following Directions, (c) Word Anagrams, (d) Logical Relations, (e) Mark Numbers, (f) Numbers and Words, (g) Information Purchase, and (h) Route Planning. A copy of the CCAB was obtained from Dr. Christine R. Hartel of ARI. A complete description of the CCAB is contained

in Samet, M. G., Gerselman, R.E., Zajackowski, F. and Marshall-Mils, J. (1986).

Subjects. Two samples of 60 subjects each were available for testing. One of these samples was taken from high flight-time Army Instructor Pilots (IPs). For each of the six aircraft mentioned above there were ten IPs for whom that was the current primary aircraft. Each subject had a minimum of 1000 flight hours in the primary aircraft. In the case of the AH-64 aircraft, subjects with 700 - 900 flight hours were considered high-time due to the recency of fielding of that aircraft. Forty of these subjects were Warrant Officers and twenty were Commissioned Officers. They ranged in age from 26 to 47 years. The other sample consisted of 60 aviation candidates. Of these, 36 were Warrant Officer Candidates and 24 were Commissioned Officers. None of the subjects in these samples had served in the small group analyses.

Procedure. Each subject was administered the background questionnaire, the daily activity log, and all four of the experimental test instruments. The CMAQ and the background questionnaire were administered to the IPs at their first computer testing session. These instruments were administered to the aviation candidates prior to their first computer testing session. During computer testing sessions one computer unit for the BAT, and two for the CCMB were available. The number of units available for the CCAB varied from two to ten. Administration times were as follows: BAT - 3 hours; CCAB - 2 hours; CCMB - 1 hour and 15 minutes; CMAQ with background questionnaire - 45 minutes.

Analysis. Stepwise Multiple Discriminant Analysis was selected to establish distinctions among the six groups of high time aviators. The subscores from the four tests were used as candidate discriminating variables for group membership. A total of 72 subscores were used in the analysis. The stepwise procedure produced a subset of these that most efficiently discriminated among the aircraft. The resulting discriminant functions were then verified by reclassifying the IPs into groups according to the discriminant functions and observing the concordance of the assignments with actual group membership. This was done both directly and using the Jackknife procedure (removal of each subject from computation of the discriminant functions). The verified discriminant functions were then applied to the test data for the aviator candidates to assign them to aircraft.

Results. Examination of the data set revealed no indication of nonlinearity in the variables, nor were there indications of extreme skewness in the score distributions. Examination of the sample variances, however, revealed a maximum ratio of 35.34:1 for variable SDSY1 between the AH-64 and CH-47 groups. The next

greatest ratio, 8.22:1 on variable LEADER, also occurred between the AH-64 and CH-47 groups. All other ratios were less than 6:1. Given the presence of very small samples and the large variance ratios, the assumption of homogeneity of variance of the variance-covariance matrices is probably not tenable.

A Stepwise Multiple Discriminant Analysis which used test battery subscores recorded from IPs to produce six aircraft groups terminated after introducing 17 of the original 72 variables in the predictor set. Although the analysis was significant [Wilk's Lambda = 0.0723, approximate $F(75, 195.8) = 1.907$, $p = 0.0002$], it failed to significantly separate groups in seven of the possible 15 two-group comparisons. The discriminant functions produced from this analysis correctly reclassified 81.67 percent of the subjects. Of the five canonical functions produced, only the first two contributed significantly to the overall analysis (combined $\chi^2(75) = 127.4$, $p = 0.0002$). These accounted for 65 percent of the total between group variance. The first function alone ($\chi^2(56) = 84.3$, $p = 0.0084$) accounted for only 38 percent of the between groups variance.

A review of the background questionnaire data for the IPs revealed that the CH-47 and AH-64 aviators typically had large enough quantities of flight time in one or more other helicopters to be considered high-time aviators in them. For example, AH-64 Instructor Pilots with 700 - 900 hours in type frequently had 2000 hours in AH-1 and 500 hours in OH-58. For IPs in the other four helicopters, flight experience was much more likely to be dominantly in a single type. Therefore it was hypothesized that the CH-47 and AH-64 IPs actually belonged to more than one group, possibly confounding the Discriminant Analysis. Given that CH-47 and AH-64 were not scheduled for immediate inclusion in the implementation of IERW-MT, these groups were removed from the data set and the Discriminant Analysis executed again.

In this case the greatest ratio of variances, 8.1:1 occurred on variable SDSY1 between the AH-1 and UH-60 groups. The next greatest ratio, 2.9:1, occurred on variable LEADER between the UH-1 and UH-60 groups. Therefore the assumption of homogeneity of variance-covariance matrices remains tentative at best. The discriminant analysis terminated with 17 variables included in the predictor set. This analysis was also significant [Wilk's Lambda = 0.0305, approximate $F(51, 60.3) = 2.6392$, $p = 0.0002$], and significantly separated groups in four of the six possible two-group comparisons. The lack of separation occurred in the comparison of the UH-1 and AH-1 groups [$F(17, 20) = 1.870$, $p = 0.0906$] and in the comparison of UH-1 and OH-58 groups [$F(17, 20) = 1.9326$, $p = 0.0799$]. The discriminant functions produced from this analysis correctly reclassified 97.50 percent of the subjects (one UH-60 pilot was incorrectly classified as a UH-1 pilot). Using the jackknife procedure to reduce the bias of

reclassification resulted in a correct classification rate of 88.65 percent.

Of the three canonical functions produced, the first two contributed significantly to the analysis [$\chi^2(51) = 99.49$, $p = 0.0001$]. These accounted for 88 percent of the total between group variance. The first function accounted for 59 percent of the between groups variance [$\chi^2(32) = 51.16$, $p = .0172$]. The canonical correlation for the first function was 0.904, indicating approximately 82 percent of the total variance is common between aircraft group membership and the 17 predictor variables. A test for equality of the covariances of the canonical functions [$M = 23.99$, approximate $F(18, 4364.1) = 1.1256$, $p = 0.3189$] was not significant. The standardized canonical discrimination function coefficients are listed in Table 2.

Table 2

Standardized Canonical Discriminant Function Coefficients

	<u>Function 1</u>	<u>Function 2</u>	<u>Function 3</u>
Tower	1.01468	0.33282	0.26663
Word Anagrams	-0.19766	-0.94064	0.71819
Mark Numbers	1.10683	0.97473	-0.51837
Numbers & Words	-1.09064	-0.19792	0.17685
Information Purchase	-0.73644	0.89444	-0.39213
Performance Composite	-1.31125	0.28699	1.05233
Cockpit Procedure & Atmosphere	0.31880	-0.79103	-0.69039
Leadership	1.20850	0.43978	0.05060
CMAQ Cluster 1	0.30109	0.19326	0.68030
CMAQ Cluster 3	-0.57643	0.28523	-0.49609
Single Dichotic Listening	-1.83953	3.74295	-2.26657
Dual Dichotic Listening	1.67248	-2.54531	2.29323
Single Tracking/ Dichotic Listening	-1.02121	-0.55952	0.28449
Dual Tracking/ Dichotic Listening	-0.85906	-1.69073	0.29334
3 Axis Tracking	0.88342	0.43572	-0.19283
Manikin	1.06659	1.36751	-0.11675
Word Knowledge	1.32751	0.01679	0.26294

The discriminant coefficients produced from this analysis are shown in Table 3. These were applied to test data taken from the sample of 60 flight students. The percentages of the student sample assigned by the discriminant functions to the four aircraft are shown in Table 4, along with the percentages of correct classification for the IPs using direct and jackknife procedures. Table 5 illustrates the coincidence of the characteristics which had been identified in the small group analyses with the behavioral constructs purported to be measured by the research battery subtests included in the discriminant functions. The included subtests have an approximately 80 percent concordance with the skills, abilities and traits identified in the small group analyses as critical to operations.

Table 3

Classification Function Coefficients

	<u>OH-58</u>	<u>AH-1</u>	<u>UH-1</u>	<u>UH-60</u>
Tower	-0.3096818E-01	-0.3842645E-01	-0.3183147E-01	-0.2629068E-01
Word Anagrams	0.8808690E-01	0.8052572E-01	0.8704776E-01	0.7074511E-01
Mark Numbers	-0.1772802	-0.1910269	-0.1822437	-0.1472893
Numbers & Words	0.9082179E-01	0.1068916	0.9764432E-01	0.8348649E-01
Information Purchase	0.7266381E-01	0.8970182E-01	0.8006078E-01	0.8091816E-01
Performance Composite	320.4010	339.7845	336.6538	319.2290
Cockpit Procedure & Atmosphere	-101.4859	-106.5237	-107.6019	-105.8042
Leadership	-63.58459	-73.44168	-65.86768	-56.67232
CMAQ Cluster 1	2.535088	2.435495	2.659146	2.627760
CMAQ Cluster 3	1.873408	2.329977	1.949866	1.944060
Single Dichotic Listening	0.4044748	0.7832269	0.5442557	0.6697529
Dual Dichotic Listening	0.6199791	0.3499966E-01	0.4710984	0.2861892
Single Tracking/ Dichotic Listening	0.9270938E-03	0.1628935E-02	0.1184953E-02	0.1653351E-03
Dual Tracking/ Dichotic Listening	0.1448790E-02	0.1328911E-02	0.1039133E-02	-0.3822131E-03
3 Axis Tracking	0.1620431E-03	-0.4047561E-03	-0.3464211E-04	0.7069260E-03
Manikin	1.843099	1.640740	1.996183	2.857444
Word Knowledge	-206.9333	-253.7745	-220.2950	-195.3552
(Constant)	-1561.797	-1703.014	-1726.109	-1616.206

Table 4

Direct and Jackknife Classifications

Direct Classification (N=40)

Actual Group	Predicted Group (Number assigned by Discriminant Analysis)				Percent Correct
	OH-58	AH-1	UH-1	UH-60	
OH-58	11	0	0	0	100
AH-1	0	10	0	0	100
UH-1	0	0	9	0	100
UH-60	0	0	1	9	90

Jackknife Classification (N=40)

Actual Group	Predicted Group (Number assigned by Discriminant Analysis)				Percent Correct
	OH-58	AH-1	UH-1	UH-60	
OH-58	11	0	0	0	100
AH-1	0	9	1	0	80
UH-1	0	0	8	1	89
UH-60	0	0	1	9	89
Students (% assigned)	15	19	9	57	

Table 5

Concurrence of Battery Subtests with Small Group Analyses

<u>Sub-Test</u>	<u>Characteristics Measured</u>	<u>SGA Identified</u>
Tower	Problem Solving/ Situational Awareness Planning	Yes
Word Anagrams	Decision Making/Pattern Recognition Memory	Yes Yes
Mark Numbers	Time Sharing/Attention to Detail Quant. Reasoning and Analysis	Yes No
Information Purchase	Decision Making/Attention to Detail Quant. Reasoning and Analysis	Yes No
Single Axis/ Dichotic Listening	Divided Attention/Reaction Time Eye-Hand Coordination	Yes Yes
Dual Axis/ Dichotic Listening	Divided Attention/Time and Resource Management/Reaction Time	Yes Yes
3 Axis Tracking	Eye-Hand Coordination/Reaction Time Divided Attention	Yes
Manikin	Spatial Transformation/ Pattern Recognition	Yes
Word Knowledge	Risk-Taking/Self-Confidence General Intelligence	Yes
CMAQ Cluster 3	High: Hostility and Arrogance Verbal Aggressiveness Competitiveness Low: Positive Expressivity Communication	No
CMAQ Performance Related Composite	High: Leadership/Cockpit Procedures Cockpit Atmosphere Personal Vulnerability	Yes
CMAQ Cluster 1	High: Ineffective/Noncommunicative Low: Striving For Achievement Work Orientation/Task Mastery Goal Orientation/Independence	No
CMAQ Leadership	High: Task Delegation/Crew Coordination/Decisiveness/ Communication Skills	Yes
CMAQ Cockpit Procedure & Atmosphere	High: Communication Skills/ Differentiate Pilot vs. Crew Functions and Procedures/ Positive Expressivity	Yes
Numbers and Words	Time Sharing/Attention to Detail Decision Making/Pattern Recognition	Yes Yes

Discussion

The profiles of aviators specializing in different rotary wing aircraft can be defined through the use of a broad approach test battery and there is potential for assignment of aviator candidates to an aircraft for which they most closely match this profile. This is the aircraft for which the candidate might be expected to have the highest probability of successfully completing flight training and of having a successful flight career. These inferences require validation, however, both in flight training performance and in the operational environment.

The discriminant analysis provides a set of classification formulas for the four current track helicopters which could be used by the USAAVNC in the actual student assignment process. The classification formulas constitute four linear regression equations using identical predictor variables with different sets of weights. The predictor variables include seven perceptual/cognitive subscores, five complex coordination/multi-tasking subscores, and five attitudinal/motivational subscores. These regression equations predict distances of a given subject from each of the four group centroids in multidimensional space. Each candidate then would receive four scores, one for each aircraft, which may be rank ordered to indicate the ordering of the candidate's "fitness" for each aircraft.

Several caveats need to be placed with this research. The size of the sample of high time instructor pilots used to establish the test battery discriminant functions was small, particularly in relation to the number of variables being estimated. The plan for this research called for twice this sample size, but the commitment to provide them could not be met. A cross validation of the discriminant analysis by random division of the original sample is therefore not a practical method for determining the degree of capitalization on chance for selection of variables. Validation of the predictor variable set for the discriminant functions must therefore be derived from other samples. The degree of correspondence between the purported domains measured by the test battery and the characteristics derived from the small group analyses, on the other hand, increases confidence in the predictor set. Another threat to the validity of the discriminant analysis exists in questionable multivariate homogeneity of variance. Although robustness of the procedures may be relied upon where sample sizes are large, the threat is greater in the presence of small samples. The threat to the assumption of homogeneity may be an artifact of the small sample or may indicate the presence of additional unidentified sub-populations. Again, assessment of this threat will require additional samples.

The classification of aviation candidates into four different helicopters at an extremely early phase of their training, after

less than 100 days of ground and flight training, posed a difficult research problem for ARIARDA. Not only was there no successful analog available to base the research upon but also the classical approach of predicting individual grades, class standing, or overall grade averages was not expected to discriminate among groups of successful aviators or aviation candidates. The extensive literature reviews and liaisons with other agencies indicated that an operational classification algorithm was obtainable only if distinctive profiles of high-time, successful pilots in different helicopters could be obtained, and if aviation candidates could be matched to these profiles. This has been accomplished, within a restricted time frame, using readily available instruments, and at a minimal cost.

References

- ARRO. Evaluation of the validity for the Mission Track Assignment Battery: Task analysis survey for the attack mission. Washington, D.C.: Advanced Research Resources Organization, 1982.
- Bordelon, V.P., & Kantor, J.E. Utilization of psychomotor screening for USAF pilot candidates: Independent and integrated selection methodologies (AFHRL-TR-86-4, AD-A170 353). Brooks AFB, TX: Manpower and Personnel Division, Air Force Human Resources Laboratory, 1986.
- Fleishman, E. A., & Quaintance, M. K. Taxonomies of human performance: The description of human tasks. New York, NY: Academic Press, 1984.
- Foushee, H.C. & Helmreich, R.L. Group Interaction and flightcrew performance. In E. L. Wiener and D.C. Nagel (Eds) Human Factors in Modern Aviation. New York, Academic Press, 1986.
- Griffin, G.R. and McBride, D.K. Multitask performance: predicting success in Naval aviation primary flight training. NAMRL-1316, Pensacola, FL: Naval Aerospace Medical Research Laboratory, March 1986.
- Helmreich, R. L. What changes and what endures: The capabilities and limitations of training and selection. In N. Johnson (Ed.) Proceedings of the Aer Lingus/Irish Airline Pilots Association Flight Symposium, Dublin, Ireland. 1983.
- Helmreich, R.L. Exploring flightcrew behavior. Social Behavior, 2, 63-72, 1987.
- Helmreich, R. L., Foushee, C. H., Bensen, R. and Russini, W. Proceeding of the Third Aviation Psychology Symposium, Columbus, Ohio, The Ohio State University, 1985.
- Helmreich, R.L. and Spence, J.T. The Work and Family Orientation Questionnaire, JSAS Catalog of Selected Documents in Psychology, 8, 35, MS 1677, 1978.
- Kantor, J., & Bordelon, V. The USAF pilot selection and classification research program. Aviation, Space, and Environmental Medicine, 56:254-257, 1985.
- Linstone, H. A. and Turoff, M. (Eds) The Delphi Method: Techniques and Applications, New York; Addison-Wesley, 1975.
- Lofaro, R.J. Methodological modifications and considerations for a new small-scale Delphi paradigm. (unpublished ARI Technical Report, 1986).

Miller, J. T., Eschenbrenner, J., Marco, R. A., & Dohme, J. A.
Mission track selection process for the Army Initial Rotary
Wing Flight Training Program. St. Louis, MO: McDonnell
Douglas Astronautics Co., 1981.

Pred, R.S, Helmreich, R.L. & Spence, J.T. The Jenkins
Activity Survey and The Type A Pattern, Unpublished
Manuscript, University of Texas at Austin, 1982.

Samet, M. G., Gerselman, R.E., Zajaczkowski, F. and Marshall-
Mils, J. Complex Cognitive Assessment Battery (CCAB):
Test Descriptions. (Technical Report AAC-TR-33211)
Alexandria, VA: Analytical Assessments Center, 1986.

Bibliography

- Air Force Human Resources Laboratory Experimental Testing, PORTA-BAT Users's Guide, The Upgrade. AFHRL/MOET, Brooks Air Force Base, TX, October 1987.
- Ambler, R.K., & Smith, M.J. Differentiating aptitude factors among current aviation specialties, NAMRL 1207, Naval Aerospace Medical Research Laboratory, Pensacola, Florida, 1974.
- Bale, R.M., Rickus, G.M., & Ambler, R.K. Factor analysis of undergraduate and postgraduate flight training grades. Aerospace Medicine, 43, 373-375, 1972.
- Bair, J.T., Lockman, R.F., & Martoccia, C.T. Validity and factor analyses of naval air training predictors and criterion measures. Journal of Applied Psychology, 40: 213-219, 1956.
- Booth, R.F. & Berkshire, J.R. Factor analysis of aviation training measures and post-training performance evaluations. NAMI 1050, Naval Aerospace Medical Institute, Pensacola, Florida, 1968.
- Campbell, D.T., & Fiske, D.W. Convergent and discriminant validation by the multitrait-multimethod matrix. Psychological Bulletin, 56, 81-105, 1959.
- Channel, R.C. Psychomotor Tests as Predictors of Success in Flight Training, Naval Reserve Air Base, Squantum, Mass., 1942.
- Dohme, J. A. Assignment of Army aviator trainees to undergraduate aeroscout mission training. Ft. Rucker, Alabama: Army Research Institute Field Unit, 1979.
- Dolgin, D. L. & Gibb, G. D. A review of personality measurements in aircrew selection. NAMRL Monograph 36, Pensacola, FL: Naval Aerospace Medical Laboratory, July, 1988.
- Fleishman, E.A. Evaluations of psychomotor tests for the prediction of pilot success: Direction control and compensatory balance tests (Technical Report AFPTRC-TR-54-131). Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, December 1954.
- Fleishman, E.A. Psychomotor selection tasks: Research and application in the United States Air Force. Personnel Psychology, 1956, 9, 449-467.

- Fleishman, E.A. Toward a taxonomy of human performance. American Psychologist, 1975, 30(2), 1127-1130.
- Fleishman, E.A., & Hemple, W.E., Jr. Factorial analysis of complex psychomotor performance and related skills. Journal of Applied Psychology, 40, 96-104, 1956.
- Fleishman, E. A., & Ornstein, G. N. An analysis of pilot flying performance in terms of component abilities. Journal of Applied Psychology, 44, 146-155, 1960.
- Fleishman, E.A., Quaintance, M.K., & Broedling, L.A. Taxonomies of human performance: The description of human tasks. New York, NY: Academic Press, 1982.
- Gopher, D. A selection attention test as a predictor of success in flight training. Human Factors, 24(2): 173-183, 1982.
- Gopher, D., & Kahneman, D. Individual differences in attention and the predication of flight criteria. Perceptual and Motor Skills, 33, 1335-1342, 1971.
- Gordon, T.A. The airline pilot: A survey of the critical requirements of his job and of pilot evaluation and selection procedures (Rep. No. 73). Washington, D.C.: Civil Aeronautics Administration, Division of Research, 1947.
- Griffin, G.R. and Collyer, P.D. Performance based standards for Naval aviators: cognitive, perceptual and multitask (CPM) functions. Naval Aerospace Medical Research Laboratory, Pensacola, FL, 1988.
- Griffin, G.R., Morrison, T.R., Amerson, T.L. and Hamilton, P.V. Predicting air combat maneuvering (ACM) performance: fleet fighter ACM readiness program grades as performance criteria. NAMRL-1333, Pensacola, FL: Naval Aerospace Medical Research Laboratory, October 1987.
- Griffin, G. R. and Mosko, J. D. Preliminary evaluation of two dichotic listening tasks as predictors of performance in naval aviation undergraduate pilot training. NAMRL-1287, Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1982.
- Harris S.D., Owens, J.M. and North, R.A. Human performance in time-shared verbal and tracking tasks. NAMRL-1259. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1979.
- Helmreich, R. L. Pilot selection and training. Paper presented at the American Psychological Association, Annual Meeting, Washington, D.C. 1982.

- Helmreich, R.L. Cockpit Management Attitudes, Human Factors, 1984, 26(5), 583-589.
- Helmreich, R.L. and Wilhelm, J.A. Human Performance in Aerospace Environments: The Search for Psychological Determinants, unpublished manuscript (1986), prepared under NASA Cooperative Agreement NCC2-286.
- Hunter, D.R., & Levine, J.M. Development of an enlisted psychomotor/perceptual test battery. (AFHRL-TR-75-60). Lackland Air Force Base, Texas: Air Force Human Resources Laboratory, Personnel Research Division, November, 1975.
- Imhoff, D.L., & Levine, J.M. (January 1981). Perceptual-motor and cognitive performance task battery for pilot selection (AFHRL TR-80-27). Brooks Air Force Base, San Antonio, TX: Air Force Human Resources Laboratory.
- Imhoff, D.L., & Levine, J.M. Development of a perceptual-motor and cognitive performance task battery for pilot selection (Final Report). Washington, D.C.: Advanced Research Resources Organization, 1980.
- Jensen, R.S., & Benel, R.A. Judgment evaluation and instruction in civil pilot training. Illinois University at Urbana-Champaign: Savoy Aviation Research Laboratory, December 1977.
- Jones, D.H., McAnulty, D.M., Shipley, B.D. and Sanders, M.G. (1984). An evaluation of the Mission Track Assignment Battery as a classification system for Army aviators. Phase I report: An examination of the ability requirements for various rotary wing missions (Technical Report ASI 479-053-84[B]. Fort Rucker, AL, Anacapa Sciences, Inc.
- Kaplan, H. Prediction of success in Army aviation training. Technical Research Report 1142, U.S. Army Personnel Research Office, OCRD, 1965.
- LeMaster, W.D., & Gray, T.H. Ground training devices in job sample approach to UPT selection and screening. AFHRL TR-74-86, Flying Training Division, Williams AFB, Arizona, December 1974.
- Lin, C. What psychological qualities should be cultivated in preparation for flight training? Hang K'ung Chih Shih (Aeronautical Knowledge No. 3, 1960, pp. 24-25. (Translation by Foreign Technology Division, Wright Patterson AFB, Ohio (AD 693 456), 1969.

- Locke, E. A., Zavala, A., & Fleishman, E. A. Studies of helicopter pilot performance: Phase II, The analysis of task dimensions. Human Factors, 1965, 7, 285-302.
- Long, G.E., & Varney, N.C. Automated Pilot Aptitude Measurement System, AFHRL-TR-75-58, Personnel Research Division, Lackland AFB, Texas, 1975.
- Majesty, M.S. The making of an aircraft pilot selection system. Officer Training School, Air Training Command, Lackland AFB, Texas, 1976.
- McAnulty, D.M., Jones, D.H., Cohen, R.J., & Lockwood, R.E. (1984). Identification of the abilities required for effective helicopter training performance (Technical Report ASI479-046-84). Fort Rucker, AL: Anacapa Sciences, Inc.
- McGrevy, D.F., Valentine, L.D. Validation of two aircrew psychomotor tests, AFHRL-TR-74-4, Personnel Research Division, Lackland AFB, Texas, 1974.
- Miller, N. E. (Ed.) Psychological research on pilot training. Army Air Forces Aviation Psychology Program Research Report No. 8 Washington: U.S. Government Printing Office, 1947.
- Myers, D.C., Gebhardt, D.L., & Fleishman, E.A. Development of physical ability performance standards for Army jobs (Final Report). Washington, D.C.: Advanced Research Resources Organization, 1979.
- Myers, D.C., Jennings, M.C., & Fleishman, E.A. (1982). Validation of cognitive and perceptual-motor tests for assigning pilots to different missions: Job analysis findings (Interim Report 3075IR). Washington, DC: Advanced Research Resources Organization.
- Myers, D.C., Schemmer, F.M., & Fleishman, E.A. (1983). Analysis of computer interactive tests for assigning helicopter pilots to different missions (Technical Report R83-8). Washington, DC: Advanced Research Resources Organization.
- North, R.A., & Gopher, D. Measures of attention as predictor training performance. Human Factors, 18(1), 1-14, 1976.
- North, R., & Griffin, C. 1977. Aviator selection 1919-1977. NAMRL Special Report 77-2. Pensacola, FL: Naval Aerospace Medical Research Laboratory.
- Hunnally, J.C. (1978). Psychometric theory (2nd ed.). New York: McGraw-Hill.

- Orlady, H. W. and Foushee, H. C. (Eds.) Cockpit resource management training: Proceedings of the NASA/MAC Workshop. Moffett Field, CA: NASA-Ames Research Center. NASA Report No. CP 2455, 1986.
- Passey, G. E., & McClaurin, W. A. Perceptual-Psychomotor Tests in Aircrew Selection: Historical Review and Advanced Concepts. HRL-TR-66-4, Personnel Research Laboratory, Lackland AFB, Texas, 1966.
- Richardson, W.G., & Rusis, G. Future undergraduate pilot training system study - Appendix VII FUPTS Student Selection and Career Considerations. Aeronautical Systems Division, AFSC Wright Patterson AFB, Ohio, 1971.
- Sanders, J. H., Valentine, L. D., & McGrevey, D. F. The development of equipment for psychomotor assessment. AFHRL-TR-71-40, Personnel Division, Lackland AFB, Texas, 1971.
- Schweitzer, J. J. Reducing attrition rate and training costs in undergraduate pilot training through improved screening and motivational methods. Air University Research study, Air University, Maxwell AFB, Alabama, 1976.
- Sheeley J. Psychological selection and testing of naval aviators and flight officers: An historical sketch, NAMRL Preliminary Draft Report, Naval Aerospace Medical Research Laboratory, Pensacola, Florida, 1977.
- Siem, F.M. The Effects of Aircrew Member Personality on Interaction and Performance. Unpublished manuscript (1985) prepared under NASA Cooperative Agreement NAG 2-137.
- Siem, F. M. & Carretta, T. R. The development and initial validation of the Basic Attributes Tests System. AFHRL, Manpower and Personnel Division, May 1986.
- Spearman, C. (1904). "General intelligence" objectively determined and measured. American Journal of Psychology, 15, 201-293.
- Spence, J.T. & Helmreich, R.L. Achievement-related motives and behavior. In J.T. Spence (Ed). Achievement and Achievement Motives: Psychological and Sociological Approaches. San Francisco, Ca: W.H. Freeman and Company, 1983.
- Spence, J.T. and Helmreich, R.L. & Stapp, J. The Personal Attributes Questionnaire JSAS Catalog of Selected Documents in Psychology, 4, 43-73, MS 617, 1974.

Stone, L.W., Krueger, G.P. & Holt, W.R. Pursuit rotor tracking performance in conjunction with extended flight operations in a helicopter simulator. Biomedical Applications Research Division, U.S. Aeromedical Research Laboratory, Fort Rucker, AL, August 1982.

Viteles, M.S. The aircraft pilot: Five years of research, a summary of outcomes. Committee on Selection and Training of Aircraft Pilots, Civil Aeronautics Administration Report #46, Washington, D.C., 1945.

Zavala, A., Locke, E.A., Van Cott, H.P., & Fleishman, E.A. Studies of helicopter pilot performance: Phase I, The analysis of maneuvers dimensions. Human Factors, 1965, 7, 273-283.